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SOIL IMPROVEMENT IN FLOOD PLAIN OF THE MISSISSIPPI RIVER USING PRE-LOAD FILL

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ABSTRACT

The pre-load method of improvement of in-situ, fine grained soils, is frequently used in practice particularly in flood plain environments. A case history is presented in which the same method was used to induce expected settlements in the existing soils before the start of construction. Total settlements and rate of settlement were monitored at two sites for a project in Jefferson County, Missouri. The results presented show that total settlements predicted using one dimensional consolidation theory are in reasonable agreement with the measured settlements in field. The results also show that in a flood-plain environment having compressible layer consisting of silty clays and silts, most of the settlement is likely to take place during placement of the fill.

KEY WORDS

Flood Plain, Preload Fill, Settlement, Soil Improvement

INTRODUCTION

With the rapid pace of industrialization, structures are often being constructed in coastal areas and in the flood plains of major rivers. However, because of the presence of soft clays in the flood plain areas, soil improvement techniques are frequently used to resist heavy loads from industrial structures, e.g, electric power plants, airports, storage tanks, cement plants etc.

There are a number of techniques used to improve the in-situ soft soils, which in their existing conditions are not suitable to support foundation loads. Pre-loading of the site with or without sand drains is frequently used to induce settlement of in-situ soils before the start of construction. This results in a significant reduction in post-construction settlements of soils. The magnitude of the preload pressure and time required to induce the desired settlements significantly depends on the consolidation characteristics of the underlying soils.

This paper presents a case history of in-situ soil improvements accomplished using preload fill without sand drains. Total settlements and rates of settlement were predicted and measured in the field at two sites for a project in the flood plain of the Mississippi River, in Jefferson County, Missouri. Results are presented to show that one dimensional consolidation theory (Lambe and Whitman, 1969) predicted total settlements within 30 percent of those measured in the field. However, the time rate of settlement estimated using the one-dimensional consolidation theory are significantly higher than those observed in the field. Results show that insitu soils consisting of silty clays and silts in a flood plain environment are likely to consolidate significantly faster than the residual soils or wind blown deposits (modified loess).

SITE AND PROJECT DESCRIPTION

The project consisted of construction of a steam-generated, electric power plant in Jefferson County, Missouri. The site is located on the west bank and in the alluvial valley of the Mississippi River. Site location of the project is shown in Fig. 1. The existing ground surface elevations at the time of subsurface investigation were in the range of El 380 to 388 feet msl. Approximately 22 to 30 feet of new fill was required to achieve the proposed elevation of El 410 to raise the site above 200 year flood stage.

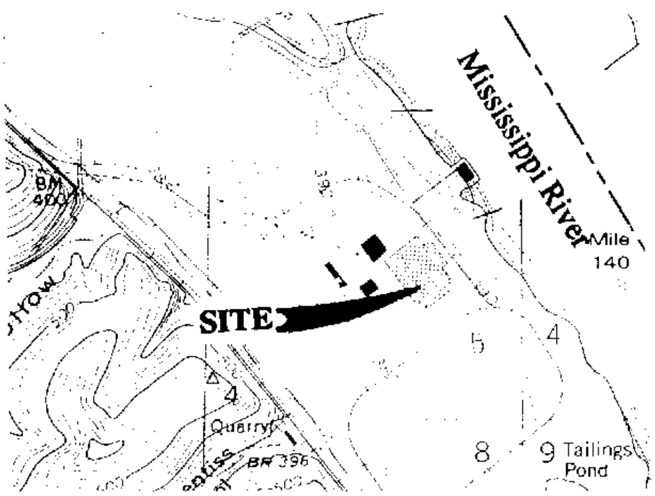

Fig 1. Site location of the project

FIELD INVESTIGATION AND SUBSURFACE CONDITIONS

Field investigation for the total project consisted of drilling ninety-seven borings ranging in depths from 16 to 145 feet. The surface of the area indicated typical ridge and swale topography approximately parallel to the river. Based on the soil conditions observed in the borings, the foundation soils at the site can be divided into two strata. The upper stratum consisted of clays and silts, approximately 10 to 30 feet thick, except in certain sloughs where the thickness approaches 50 feet. The stratum of clays and silts was underlain by a stratum consisted of fine to coarse sands approximately 80 to 120 feet thick. Some buried silt and clay lenses were also present in the sand formation. Limestone bedrock was encountered at depths of approximately 120 to 140 feet from the existing ground surface, near the river. The depth to rock was observed to decrease rapidly to a depth of 30 to 40 feet near the western edge of the site, away from the river. Soil profiles of the top stratum at the preload fill test sites, Sites 1 and 2, are shown in Fig. 2.

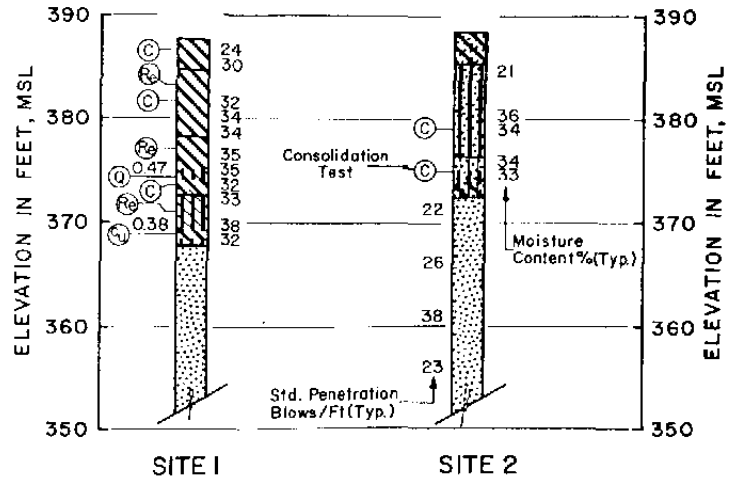

Fig. 2 Upper stratum soil profiles at Sites 1 and 2

The consistency of the upper stratum of clays and silts was observed to be soft to medium stiff (s_u in the range of 0.20 to 0.40 tsf), typical for the flood plain of the Mississippi River in Jefferson County, Missouri. Moisture contents at the preload fill test sites generally varied between 30 and 35 percent. Liquid limits of the silts and clays were observed to be between 37 and 48 at Site 1 and between 30 and 38 at Site 2. Plastic limits at both sites were observed to be between 23 and 26. From the consolidation tests, the over consolidation ratio (OCR) of the soil was estimated to be between 1.5 and 2 except for samples obtained near the ground surface where over consolidation ratios above 6 were measured. The Compression index of the existing soils was estimated to be between 0.28 and 0.34 except for a sample near the ground surface where a compression index of 0.16 was measured. High over consolidation ratios and low compression indices of the existing soils near the ground surface show some desiccation of the surfacial soils. The in-situ sands were observed to be medium dense to dense with measured blow counts in the range of 20 to 40.

PRELOAD TEST FILLS

Two preload test fills were constructed on the site to measure settlement characteristics of the existing soils at the project site. Plan and elevation dimensions of the preload fills at Sites 1 and 2 are shown on Figs. 3 and 4, respectively.

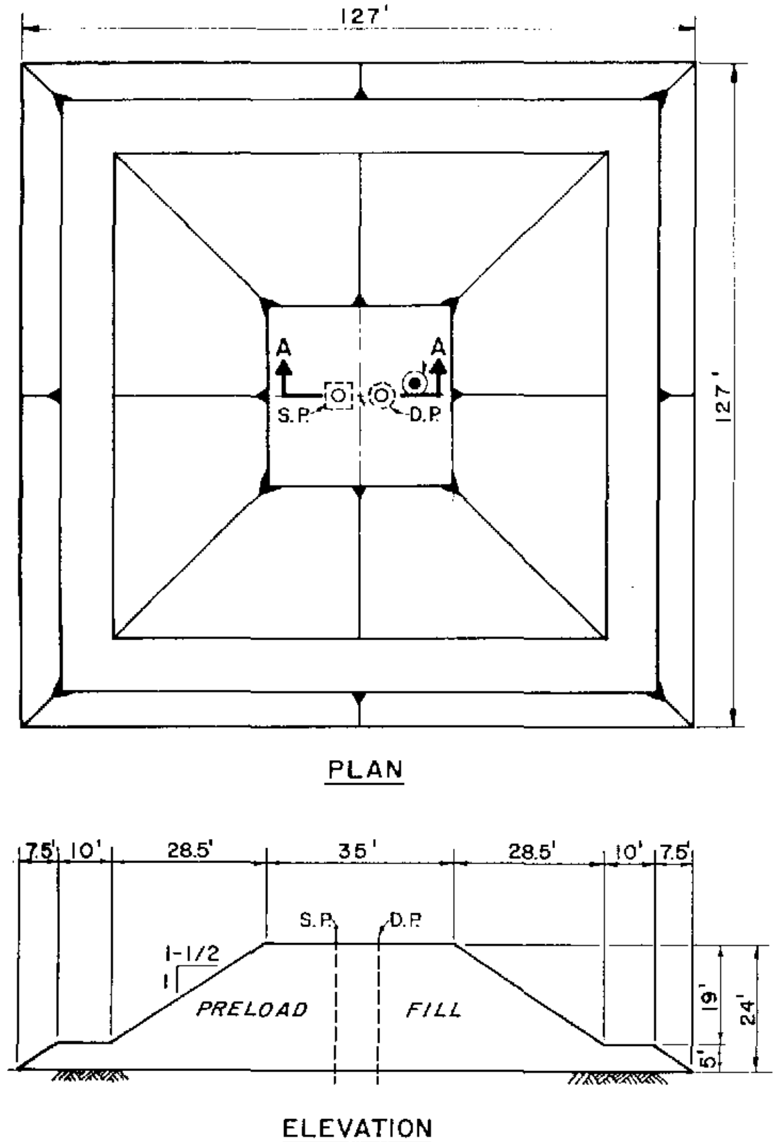

Fig. 3. Plan and elevation dimensions at Test Site 1

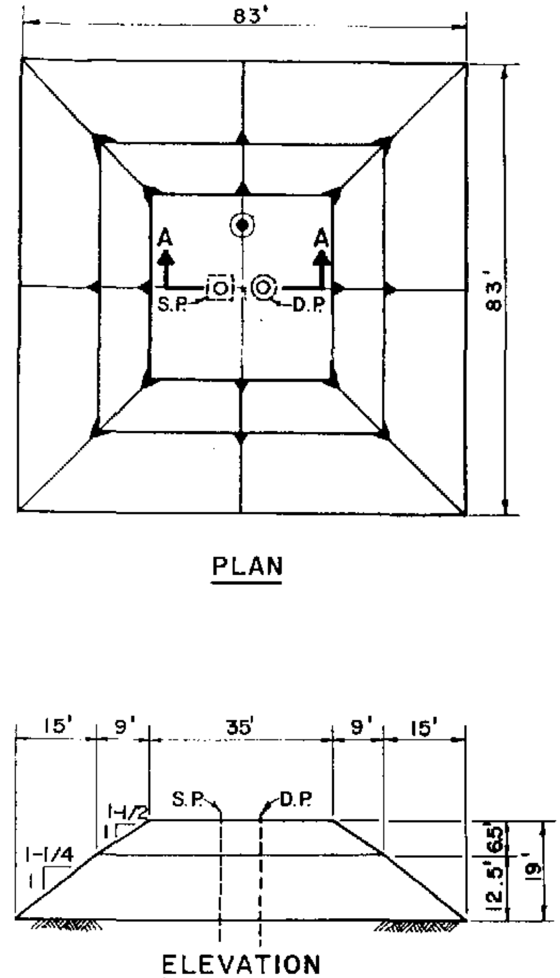

Fig. 4 Plan and elevation dimensions at Test Site 2

Two settlement plates were installed at each preload site. The settlement plates are referred to as SP (Shallow Plate) and DP (deep Plate). Details of the settlement plates used for measuring settlements in the existing soils are shown in Fig. 5.

Preload Test Fill at Site 1. The top stratum of the existing soils at the location of preload test fill, Site 1, predominantly consisted of 20 feet thick layer of silty clay. The preload fill was constructed of uncompacted loose fill to a height of 24 feet. The fill was 35 feet square at the top and had side slopes of 1 Vertical to 1.5 Horizontal (1V:1.5H). A 5 foot high and 10 foot wide stabilizing berm was constructed around the bottom of the preload fill after placement of preload fill.

Density tests taken from the fill indicate an average wet density of approximately 115 pounds per cubic foot (pcf).

Preload Test Fill at Site 2. The top stratum of the existing soils at the location of preload test fill, Site 2, essentially consisted of 16 feet thick stratum of silts with clay seams. The preload fill at Site 2 was constructed of compacted fill from a base dimension of 90 feet square with a side slope of 1V:1.25H up to a height of 13 feet. Loose fill was placed from 13 feet to the maximum height of 19 feet with a slope of 1V:1.5H making the fill approximately 35 feet square at the top. No density tests were made of the preload fill material at Site 2 but a density of 115 pounds per cubic foot (pcf) was assumed from loose preload fill.

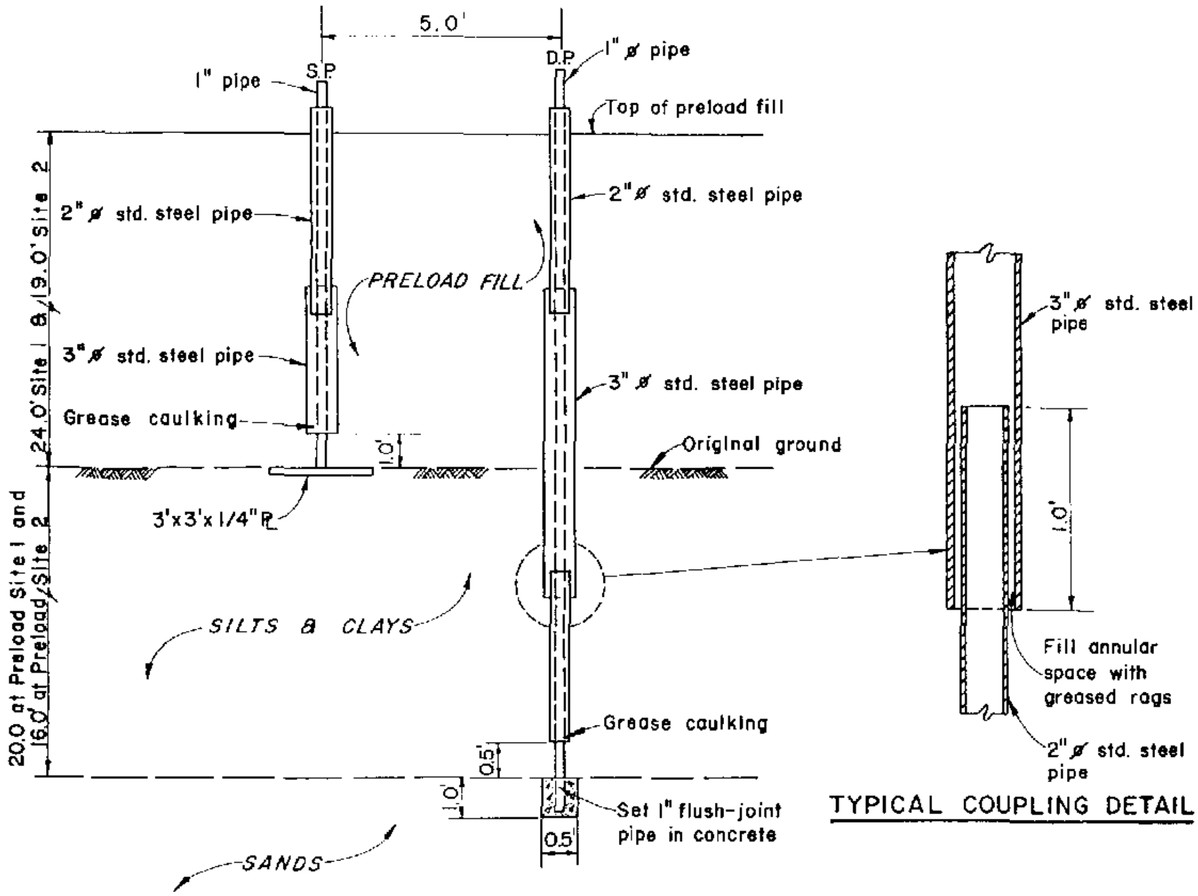

Fig.5 Details of shallow and deep settlement plates

SETTLEMENT OBSERVATIONS

Fig. 6 shows settlements observed and elevation of fill with time at Site 1. Similar observations for Site 2 are shown on Fig. 7. As shown in Fig. 6, total settlements of 0.12 feet and 1.25 feet were observed at shallow and deep settlement plates, respectively, resulting from the weight of the fill (increase in pressure of 1.4 tsf). Based on the laboratory test results, settlement of 0.9 feet was computed which is approximately 72 percent of the measured settlement of 1.25 feet. Readings from the deep settlement plates appear to be in error. Fig. 6 also shows that approximately 90 percent of the total settlement in the clay stratum occurred as the load was placed. Fig. 7 shows that the total settlements of 0.05 feet and 0.55 feet were observed at the deep and shallow plates, respectively. Total settlement of 0.60 feet was computed using data from consolidation tests performed in laboratory. Fig. 7 shows that approximately 90 percent of the total settlement took place within 2 days after placement of the fill.

Time required for 90 percent of the total settlement to take place was computed to be between 30 and 50 days using one-dimensional consolidation theory. A coefficient of consolidation, C_v, of 1 ft^2/day was used to compute the time required for completion of 90 percent of the settlement (Holtz and Kovacs, 1981 and NAVFAC, 1971). However, as shown in Figs. 6 and 7, consolidation of the existing soils was significantly faster than that predicted and most of the settlements were complete within 2 days of placement of the preload fill. This shows that in flood plain environments, the time rate of settlement estimate using one-dimensional consolidation theory may be conservative.

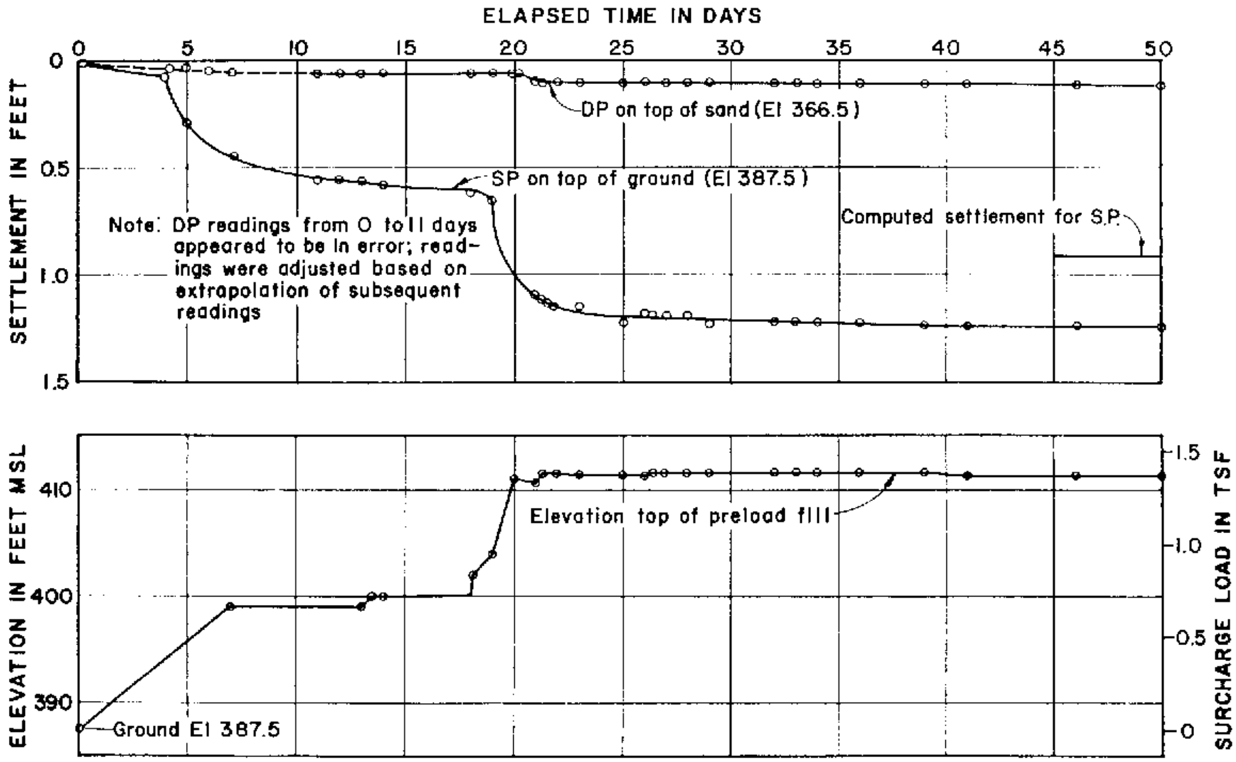

Fig. 6 Settlements observed and elevation of pre-load fill with time, Site 1

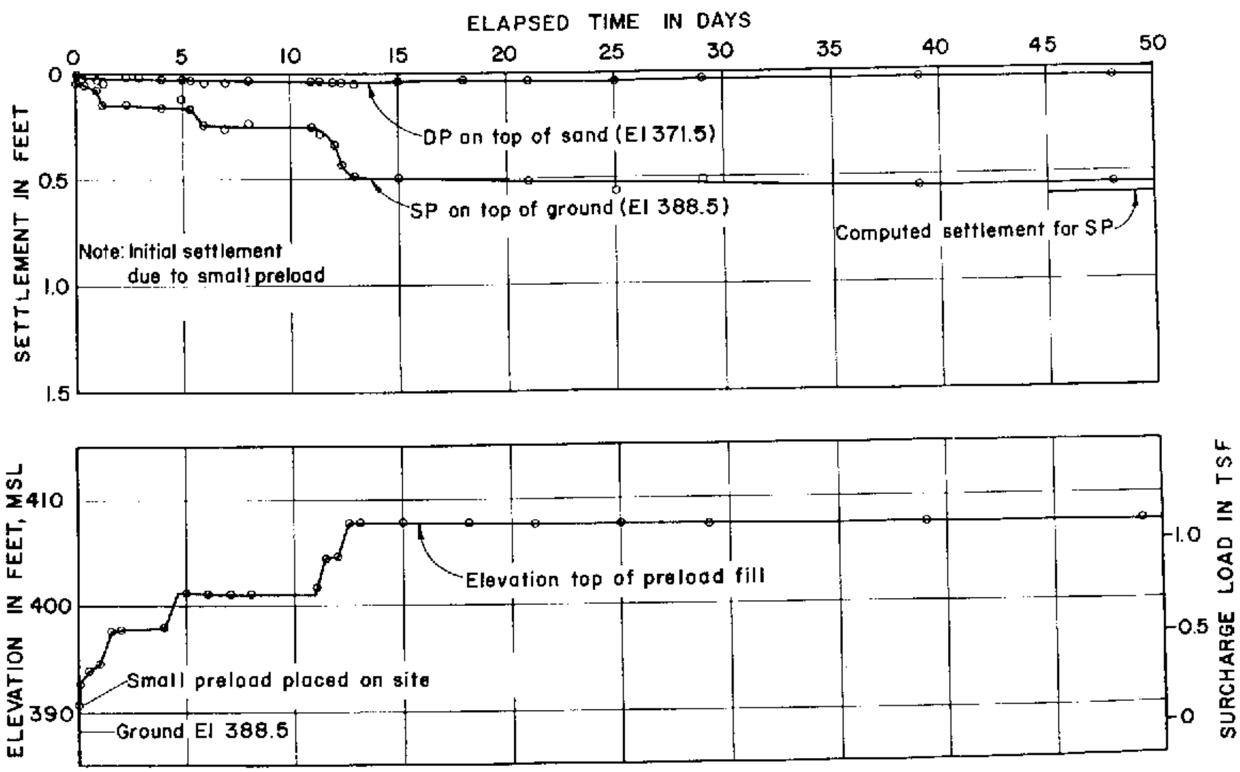

Fig. 7 Settlements observed and elevation of pre-load fill with time, Site 2

The faster rate of consolidation in flood plain environments may be because of the presence of thin layers or lenses of relatively large permeability silts and sands within the compressible stratum which acts as drainage paths for expulsion of water during consolidation, thus increasing the rate of consolidation. Therefore, it is the authors' opinion that when estimating the time rate of settlements in the flood plain environments where the compressible soil stratum consists of silty clays and silts, consideration should be given to the likelihood of the presence of thin layers or lenses of silts and sands in compressible layers, and an effective length of the drainage path should be used to compute time rate of settlements.

CONCLUSIONS

Based on the theoretical estimates and measured settlements it was concluded that settlements in the range of 0.5 to 1.5 feet may occur at the site under the weight of the plant fill. The total settlement will depend on the thickness and characteristics of the compressible stratum at any given location. It was concluded that most of the settlements due to plant fill will be completed within 5 to 10 days after completion of the fill.

Results presented here show that in a flood plain environment where the compressible soil layer consists of silty clays and silts, most of the expected settlements are expected to take place during the placement of the fill. This may be because of the presence of thin layers or lenses of relatively large permeability silts and sands within the compressible stratum. Total settlement measured at Site 1 was approximately 30 percent higher than that predicted using one-dimensional consolidation theory. Total settlement measured at Site 2 was close to the predicted settlements.

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